CHINESE MAIZE: FRONT AND BACK VIEW OF THE SAME PLANT.

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B. T. GALLOWAY, *Chief of Bureau.*

A NEW TYPE OF INDIAN CORN FROM CHINA.

BY

G. N. COLLINS, Assistant Botanist.

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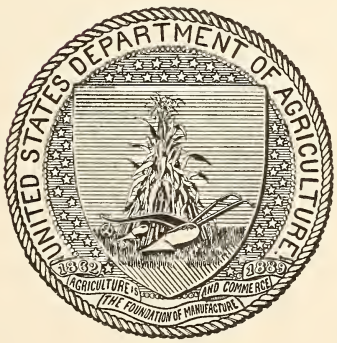

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BIONOMIC INVESTIGATIONS OF TROPICAL AND SUBTROPICAL PLANTS.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., August 12, 1909.

Sir: I have the honor to transmit herewith a paper entitled "A New Type of Indian Corn from China," by Mr. G. N. Collins, Assistant Botanist of this Bureau, and recommend its publication as Bulletin No. 161 of the Bureau series.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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A NEW TYPE OF INDIAN CORN FROM CHINA.

INTRODUCTION.

In March, 1908, a small sample of shelled corn was received by the Office of Foreign Seed and Plant Introduction from Rev. J. M. W. Farnham, of the American Presbyterian Mission at Shanghai, China, with the following note:

> A peculiar kind of corn. There are several colors, but they are said to be all the same variety. The corn is much more glutinous than other varieties, so far as I know, and may be found to be of some use, perhaps as porridge.

Plants were grown from this seed in the season of 1908 and proved to be quite unlike any of our cultivated varieties or those known from Tropical America. They possessed a number of unique characters, no indication of which is found in any of the forms of *Zea mays* thus far recorded. Since this new type of maize thus extends the range of diversity of the species and enhances the possibilities of breeding by providing additional characters and adaptations, it appears desirable to place on record a description of the variety, with an enumeration of its peculiarities. Several of the unique features combine to enable the plant to resist the drying out of the silks by dry, hot winds at the time of flowering.

Although the plants and the ears they produce are so small that the variety would probably find no place in direct competition with our improved varieties, the possession of this adaptation gives the new type an economic interest, particularly in some parts of the semiarid Southwest. In these regions a hot desert wind at the time of flowering will dry the silks before the grains have been pollinated, and often causes a complete failure of the crop, even under conditions not otherwise unfavorable. This danger would be greatly reduced if our varieties had some of the habits of this Chinese corn, and the effort is now being made to combine, by hybridizing, the desirable characters of this small variety with those of larger and more productive types.

Another noteworthy feature of this corn is the character of the endosperm, which is quite distinct from the horny, starchy, or sweet endosperms of the varieties hitherto known in the United States. In view of the recent development of specialized corn products as human food, this unique type of starch may be of some economic importance.

DESCRIPTION OF VARIETY.

The seed of this corn as originally received from China was a mixture of yellow, white, and red grains, many of the latter being more or less mottled. Separate plantings were made of the yellow, white, and red colors and of the mottled grains. No differences in the behavior of the different plantings were detected, and the following description applies to the whole series.

The seed was planted near Washington, D. C., on May 9, 1908, and 53 plants were grown to maturity. The first pollen was shed eighty-two days after planting and the seed was harvested one hundred and thirty-nine days from planting, at which date most of the seed had been mature for some time. As a rule the silks appeared on the individual plants at about the time that the last of the pollen was being shed. One stalk was noted with silks at two ears, while the plant was still producing pollen. Suckers were produced by 40 per cent of the plants.

The plants were of small stature, ranging from $3\frac{1}{2}$ to 6 feet in height; the average circumference of the stalk at the smallest point of the largest internode was slightly less than 3 inches. The number of nodes above the ground ranged from 11 to 15, with 4 nodes above the ear. The average number of green leaves at the time of tasseling was 12. The blade of the fifth leaf from the top averaged $31\frac{1}{2}$ inches long by $3\frac{1}{3}$ inches wide. The longest leaf sheath averaged $7\frac{1}{2}$ inches. The plants produced from 1 to 3 ears, a single ear at a node in every case. The ears were small and slightly tapering, averaging $5\frac{1}{2}$ inches long by $4\frac{1}{3}$ inches in greatest circumference, with 16 to 18 rows of small grains. Nothing unusual in the size or distribution of the roots could be observed.

Except for their short, stocky habit of growth the plants showed no unusual behavior until after the leaves of the last four or five nodes began to appear. These leaves were formed in rapid succession, with very short internodes, and it was then noticed that on a large proportion of the plants the blades of the leaves were all on one side of the main stem. Thus the upper part of the plant, instead of having the usual distichous or two-rowed arrangement of the leaf blades, might be described as having a one-rowed or monostichous arrangement. While in only about 25 per cent of the plants were the upper leaf blades completely monostichous, all of them showed a tendency in this direction. This one-ranked appearance is brought about by a twisting of the leaf sheaths, the actual insertion of the leaves being opposite, as in all grasses.

In addition to the unusual position of the leaves the blades of the upper nodes were erect instead of spreading or drooping, as in other varieties. The midrib of the blades did not form an angle with the sheathing base of the leaf, but continued upward in a straight line.

The internodes on the upper part of the plant were also much shortened, so that the tassel was not carried up, as in other varieties, but was considerably exceeded by the tips of the leaves.

The tassel was moderately compact, with from 14 to 30 primary branches, many of which were again branched. The spikelets were arranged in alternate groups of two, after the manner of most of our cultivated varieties. Nothing unusual was observed in the flowers. Pollen was produced in great abundance, and over a period of about five days in individual plants.

The following is a tabulation of the measurements of eighteen plants, the seed of which was hand-pollinated either in the production of hybrids or for the study of characters in pedigreed stock:

TABLE I.—*Measurements and details of growth of eighteen plants of Chinese corn.*

Designation of plant by number.	Days from planting to first pollen.	Days to first silks.	Green leaves.	Length of fifth leaf from top.	Width of fifth leaf from top.	Length of longest leaf sheath.	Primary branches in tassel.
	No.	*No.*	*No.*	*Cm.*	*Cm.*	*Cm.*	*No.*
1	.....	.....	9	63	7	15	14
2	.....	99	12	74	7	.....	16
3	97	.....	13	67	8.5	17	.....
4	.....	.....	10	85	9	22	20
5	81	85	11	81	8	17	16
6	82	86	13	84	9	19	24
7	86	93	13	88	8.5	22	30
8	.....	.....	11	85	9	20	.....
9	.....	94	14	88	9	20	18
10	105	.....	10	70	6	20	.....
11	96	100	13	83	9	18	26
12	.....	.....	12	75	8	17	.....
13	.....	.....	9	96	7	21	19
14	92	106	13	88	10	21	20
15	102	.....	13	83	9.5	19	28
16	86	89	13	78	9	19	18
17	94	98	12	86	9	21	.....
18	.....	.....	12	75	8	17	17
Average	92.1	94.4	11.8	80.5	8.4	19.1	20.5

Designation of plant by number.	Height.	Circumference.	Internodes.	Ears.	Internodes above ear.	Length of ear stalk.	Suckers.	Layers of husks.
	Cm.	*Cm.*	*No.*	*No.*	*No.*	*Cm.*	*No.*	*No.*
1	117	5.5	11	1	4	.....	1	.....
2	142	8	.....	2	4	11	0	.....
3	142	7	13	.....	4	7	1	5
4	184	7	15	1	4	8	0	.....
5	120	6.5	11	1	4	10	.....	7
6	130	9.5	13	3	4	18	1	.....
7	170	9	13	2	4	17	2	.....
8	.....	.....	12	.....	4	.....	1	.....
9	176	10	15	2	5	10	2	6
10	.....	6	14	1	5	6	.....	.....
11	167	8	14	2	4	8	0	7
12	145	8	13	2	5	.....	.....	.....
13	180	6	14	1	4	7	.....	6
14	180	9	15	2	6	8	.....	.....
15	189	8	14	2	.....	16	0	6
16	162	8	13	2	4	10	0	5
17	160	8.5	13	.....	4	8	1	7
18	145	8	13	2	5	.....	.....	.....
Average	156.8	7.8	13.3	1.7	4.4	10.3	0.8	6.1

DISTINCTIVE CHARACTERS.

The following are the characters which distinguish this Chinese corn from our United States varieties as well as from any of the forms thus far observed in Tropical America. It should not be overlooked that the plants on which these observations were made were grown in an entirely new environment and that some of the characters exhibited may not be normal to the variety. Should this prove to be the case, however, these unique characters still show the possibilities of the species and are scarcely less interesting in the new connection.

Erect leaf blades.—The leaf blades of the upper nodes are in most cases erect, the midrib of the blade and the back of the leaf sheath forming a straight line. The leaves on the lower part of the plant are borne at the customary angle, but each succeeding leaf is slightly more erect than the preceding until they become completely erect on the last two or three nodes. Our common varieties exactly reverse this behavior, the blades that are somewhat erect being on the lower part of the plant, each succeeding blade being more nearly horizontal.

Our cultivated varieties vary greatly with respect to the angle of the blades, but nothing has been observed that approaches the definitely erect position of the blades in the Chinese variety. What at first appeared to be an approximation was seen in a type of corn from Colombia. A considerable series of varieties from different parts of that country, while not in the least resembling the Chinese corn in other particulars, had very erect leaf blades. The resemblance is, however, more apparent than real. The blades that are erect in the Colombian varieties are not those that immediately precede the tassel, but are several nodes lower down. Few of the Colombian varieties mature in the United States, and the uppermost leaves that are produced, though perhaps 20 feet from the ground, are still several nodes from the tassel. If the Colombian plants should reach maturity the blades that correspond to the erect blades of the Chinese variety would probably be borne much more nearly horizontal.

A much closer approximation to the erect blades of the Chinese variety was found in a single plant of a variety of dent corn secured from Brownsville, Tex. In this specimen the uppermost blade made an angle with the sheath of only 5°, although other plants of the same variety had the leaf blades borne at the customary angle. The plant with the upright leaves was also abnormal in other respects. In observing the range of this character the other extreme was found in drought-resistant varieties from the table-land of Mexico, which have the uppermost leaf blades bent away from the stalk at an angle of over 90°, or below the horizontal.

Monostichous arrangement of leaf blades.—The most striking peculiarity of this Chinese variety is the one-sided appearance of most of the plants, caused by having the leaf blades on the upper part of the plant all on one side of the stalk. This character is shown in Plate I, figures 1 and 2, which represent opposite sides of the same plant, and in Plate II, figure 2, a more detailed view of the upper part of a plant, showing the bases of the blades in their natural size and position.

This monostichous habit is definitely correlated with the erect position of the blades and follows almost as a necessary consequence. If the erect blades were arranged in the ordinary manner they would almost entirely inclose the silks and very greatly reduce the chances of pollination. The erect position of the blades, in connection with the monostichous habit, constitutes an almost ideal arrangement for insuring pollination. In the most extreme case the leaves of the fifth or sixth node from the base of the plant begin to show a deviation from the normal alternate arrangement, but in most cases only the last four or five leaves are distinctly on one side.

With the exception of the single abnormal plant in the Brownsville variety already mentioned, little tendency toward this monostichous habit was observed in any other variety, and the character seems never to have been recorded.

As a consequence of the monostichous habit the top of the plant is curved or scorpoid. The crowding of the leaf blades on one side of the plant necessarily displaces the top, so that it curves toward the open side of the plant. In the most pronounced cases the tip of the plant is curved to such an extent that the last leaves pass the perpendicular and bend forward over the tassel, with the back of the leaf uppermost.

Development of silks by ears while still inclosed in the leaf sheaths.—A third character associated with the erect blades and monostichous habit is the production of the silks directly at the junction of the leaf blade and sheath. This character, while by no means so rare as the two preceding, does not appear, so far as the writer knows, in any of the varieties of field corn now cultivated in the United States. It is brought about by the development of the silks at an early stage, before the ear stalk has elongated and while the young ear is very small. The silks appear at the base of the leaf, where it joins the sheath before there is any other indication of an ear, except a slight swelling of the leaf sheath.

A similar tendency to produce the silks before the young ear emerges from the leaf sheath is also shown by several entirely unrelated types from the American Tropics, but appears to be confined to varieties from regions that are subjected to severe drought.

Waxy endosperm.—The most distinctive character possessed by this Chinese variety is the nature of the endosperm, which is entirely unlike that of any of the known varieties of corn. A discussion of this character occurs on page 14, where the characters of the grain are described.

RESISTANCE TO DRY WINDS.

The combination of the three characters—erect leaf blades, monostichous arrangement of leaf blades, and silks borne directly in the angle where the blade joins the sheath—combine to constitute a most beautiful adaptation that prevents the drying out of the silks before pollination. The erect, overlapping blades catch all pollen that is blown against the upper part of the plant and allow it to settle in the channels at the base of the blades, where it accumulates in considerable quantities. The receptive silks are then pushed into this accumulation of pollen and can thus become fertilized before they are ever exposed to the air.

With our ordinary varieties of Indian corn the ear is usually pushed out a considerable distance, often from 6 inches to a foot above the base of the leaf, before the silks appear. The moist, receptive stigmas are thus fully exposed to the air, and if pollen is at all scarce it may be several days before the majority of the silks are pollinated. The delicate silks are very susceptible to injury from drought, but where pollen is produced over a considerable period no permanent injury may be done, for the silks that are not pollinated continue to grow and to produce new stigmatic surface for a week or more.

In the semiarid district of the Southwest this continued growth of the silks is often of no avail. If the production of pollen is held in check for a few days by cool, moist conditions the dry, hot weather which often follows abruptly brings all the pollen to maturity within a very few days and at a time when the silks are too dry to be pollinated.

Even where the silks are not destroyed by drought, pollination is often imperfect. Though the pollen is produced in great abundance,[a] it is so thoroughly scattered by the wind that the chances of each silk receiving its grain of pollen are by no means complete. In the Chinese corn, however, the pollen is literally collected and held in readiness so that each silk must come in contact with many grains.

This combination of characters, while constituting an effective adaptation against drought at the time of flowering, might have its disadvantages if moist conditions prevailed. The accumulation of

[a] Individual plants are estimated to produce from 10 to 70 millions of pollen grains. (See Lazenby, W. R., The Blossoming and Pollination of Indian Corn, Proceedings of the Meetings of the Society for the Promotion of Agricultural Science, vol. 13–16, 1896–1899, p. 127).

pollen in the axils of the blades if kept moist would form an excellent medium for the development of molds, bacteria, and fungi.

As the upright blades of the leaves always extend above the tassels it seems that the chances of self-pollination must be greater than usual, especially since in this Chinese variety the tassels do not appear much before the silks. The production of more than one ear on each stalk, which is usual in this variety, would to some extent correct the tendency to self-pollination, for in practically all cases the second ear must be cross-pollinated. In regions where high winds prevail at the time of flowering, the percentage of self-fertilized grains would be further reduced.

This adaptation would be still more perfect if the plants were oriented so that the open side of the plant was presented to a prevailing wind. In our experimental planting the plants appeared to face indifferently in all directions, but the number of plants was small and if any tendency toward a definite orientation existed the wind would doubtless be the exciting cause, while in the absence of a definitely prevailing wind such orientation could hardly be expected.[a]

CLIMATE OF THE REGION WHERE THE TYPE WAS DISCOVERED.

The climate of the vicinity of Shanghai where Doctor Farnham found this corn is not shown by the available meteorological data to be of the exacting nature which might be expected to call forth a special adaptation against drought. The characters of the plant do not indicate a general resistance to drought, but rather an adaptation against dry winds at the time of flowering. These periods of drought might be of such short duration that no indication of them would be given by ordinary meteorological data on rainfall and humidity. Short periods of drought do occur in many regions and have little effect on the total monthly rainfall and average humidity, but are nevertheless an important factor in determining plant growth. It is also not improbable that the variety here described was originally from the northern part of China, where extreme droughts during the summer months are the rule. If this is the case, the cultivation of this variety, even in China, must be somewhat restricted, for Mr. Frank N. Meyer says that nothing resembling this type was seen by him in the northern part of China, where he traveled for nearly three years, making a study of the agriculture of that region.[a]

DESCRIPTION OF GRAIN.

Color.—The original seed was very much mixed with respect to color. A majority of the grains had a yellow endosperm and a dull ruby-colored aleurone layer. Few were pure white and a still smaller number a very light lemon-yellow.

The color of the aleurone layer was distinct from anything that has been observed in other varieties. It varied greatly in intensity.

[a] See note on page 25.

In rare cases it approached the bluish black of our common "black" varieties, but for the most part varied from a dull ruby to maroon. The color was usually confined to the top of the seed, fading out toward the base and sometimes slightly mottled. The pericarp was in all cases transparent.

The location of a red color in the aleurone layer is in itself a rather unusual character. As a rule in red varieties the color is located in the pericarp or outside coat of the seed. The aleurone, or the layer of cells immediately inside the seed coat, if colored, is usually some shade of blue, which may vary from slate color through purple to black. There is one well-known exception, the Voorhees red sweet corn, which has a dark-red aleurone. It is interesting to note that this variety originated by crossing a white variety (colorless aleurone layer) and one which had a blue-black aleurone.[a]

Size and shape of kernels.—Most of the seeds are cuneate with rounded tops, straight sides, and pointed bases, though there were many broader seeds with blunt bases. The cross section is circular or indistinctly hexagonal, the transverse diameter being only slightly greater than the longitudinal. In the form and size of the kernels, as well as in the appearance of the ear, this corn is very similar to a type commonly grown in southern and southeastern Europe.[b]

In the original seed the size was very variable, due largely to the presence of poorly formed grains. The white seeds were somewhat more uniform and slightly larger than those with red aleurone. The red seeds averaged 7 mm. long and 5.8 mm. in greatest width (50 seeds measured), while the same number of white seeds averaged 7.4 mm. long and 6.1 mm. wide. The average weight of the red seeds was 0.098 and of the white 0.122 gram.

New type of endosperm (waxy endosperm).—The texture of the endosperm is one of the unique features of this corn. There is a very small amount of the amylaceous or starchy endosperm, about as it appears in the common varieties of pop corn. The remainder of the endosperm occupying the position of the corneous or horny endosperm of our ordinary varieties is quite distinct in its appearance and mechanical characteristics, and must be considered as constituting another type of endosperm in addition to the amylaceous or starchy and the corneous or horny endosperm possessed by flint, dent, and soft varieties.

This new type of endosperm is undoubtedly more closely related to the corneous endosperm and occupies the same position in the

[a] Halsted and Kelsey. Bulletin 170, New Jersey Agricultural Experiment Station. 1904.

[b] Mr. J. D. Shanahan, of the Bureau of Plant Industry, states that these varieties with small grains command a special price in England, where they are in demand as a food for pheasants.

grain, but its physical properties are strikingly different. It is less glassy than the corneous endosperm, though nearly as hard. Cut in any direction it separates with a sort of cleavage, exposing a dull, smooth surface. Instead of being translucent it is completely opaque, though not in the least approaching the coarse opaque texture of the amylaceous endosperm. The texture suggests that of the hardest waxes, though it is still harder and more crystalline. From this optical resemblance to wax the term cereous or waxy endosperm is suggested. Like the corneous endosperm it is either white or yellow, while the amylaceous endosperm, so far as observed, is always white. The opaque nature of this cereous endosperm is especially evident when grains with a colored aleurone layer are cut. When colored grains with a corneous endosperm are cut the translucent nature of the endosperm causes it to appear colored like the aleurone layer, while in the Chinese corn the endosperm appears in its true color, white or yellow, unaffected by the color of the aleurone.

Composition of seed.—The appearance and physical composition of the seeds of this Chinese corn were so distinct from that of other varieties that the possibility of a difference in chemical composition naturally suggested itself, but analyses did not yield any very unusual results. Analyses of two ears, apparently similar, showed very different percentages of oil and protein, but all within the limits reported from analyses of American varieties.

With a view to ascertaining something of the range of composition in different types of corn a series of twenty-one varieties was analyzed and appears in the table below, arranged in order of the percentage of protein. The analyses were made by the Bureau of Chemistry of this Department from samples thoroughly air dried. The oil and protein are calculated on a water-free basis.

TABLE II.—*Chemical analyses of twenty-one varieties of Indian corn.*

No. of variety.	Class of corn.	Source.	Protein.	Oil.	Water.	Weight of 1,000 seeds.
			Per cent.	*Per cent.*	*Per cent.*	*Grams.*
1	Pop	Hungary	13.31	5.46	9.05	122
2	Soft	Hopi Indians, Arizona	12.49	6.87	9.48	254
3	do	do	12.10	7.58	10.08	
4	Flint	Argentine	11.84	5.66	8.95	241
5	do	Rhode Island	11.80	5.06	9.81	
6	Wax (new Chinese type)	China	11.80	6.12	10.11	
7	Dent	Colombia	11.63	4.23	9.63	493
8	Soft	Hopi Indians, Arizona	11.00	6.82	10.53	
9	Dent	Chiapas, Mexico	10.61	5.37	9.34	560
10	Soft	Tuscarora Indians, New York.	10.01	5.80	9.27	403
11	Flint	North Dakota	9.90	5.51	9.87	
12	Dent	Illinois	9.75	4.48	9.83	
13	do	do	9.65	4.60	9.80	
14	Soft	Hopi Indians, Arizona	9.50	6.20	9.67	
15	Chinese hybrid, corneous endosperm.	China	9.28	4.49	9.09	132
16	Pop	Algeria	9.19	5.98	8.25	121
17	Dent (shoe-peg)	Vera Cruz	8.74	6.39	10.52	349
18	Soft	Chihuahua, Mexico	8.46	5.64	9.31	336
19	Pop	Toluca, Mexico	8.35	6.36	10.06	81
20	Wax (new Chinese type)	China	8.26	4.12	9.01	98
21	Dent	Chihuahua, Mexico	8.05	4.98	8.67	190

Table II shows that the chemical composition of the seeds of corn stands in no direct relation to the type of grain. Similar varieties are widely separated with respect to amount of protein and oil, and such diverse types as the soft corns and the pop corns may show a closely similar chemical composition. Thus one variety of soft corn stands next to the top in percentage of protein and a similar variety is fourth from the last. One variety that must be classed as a pop corn heads the list, with 13.31 per cent of protein, while another variety of pop corn from Mexico is third from the last, with 8.35 per cent. It is further interesting to note that the variety of soft corn grown by the Hopi Indians stands first in percentage of oil, second in percentage of protein, and third in amount of water.

It has frequently been noted that the composition of different ears of a uniform strain shows diversities of the same order as that found in a series of varieties. Even the very distinct types included in the above series show only a slightly greater range than that usually found in a similar number of ears of a single uniform variety.

Crossing the Chinese corn with other varieties seems to have the effect of increasing the percentages both of oil and of protein in the same season that the cross is made. Seed from an open-pollinated ear that had received foreign pollen, as shown by the corneous nature of the endosperm, showed an increase of 1.02 per cent in oil and 0.37 per cent in protein over the pure seed from the same ear.[a]

XENIA.

During the season of 1908 a number of hand-pollinations inside the variety were made, and ten hybrids were also secured between the Chinese corn and other varieties. These ears afford an opportunity for preliminary observations regarding the behavior of hybrid characters that appear in the F_o generation; that is, in the same year that the cross is made.

ALEURONE COLOR.

The red aleurone color appears in general to be prepotent when crossed with white varieties. A cross between two plants both from red seed produced an ear with 398 seeds, 312 showing the red color and 86 without, a ratio of 1:3.6+. Assuming that both plants were heterozygotes (i. e., crosses of red and colorless individuals) the expectation, according to Mendel's law, would be 1:3 or 298.5 and 99.5 ± 18.4. Another cross between a plant from a red

[a] Scherffius reported no change in the protein content of hybrid seed compared with pure seed of the same ear; based on analyses of white seeds that appeared on open-pollinated ears of Reid yellow dent, Yellow Leaming, and Riley's Favorite. See Bulletin 122, Kentucky Agricultural Experiment Station, p. 188.

seed and a white variety of starch corn from Chihuahua, Mexico, produced an ear with 431 seeds, 381 with colored aleurone and 50 without color; the expected ratio would be either all colored if the female were pure, or equal numbers of each if the female were heterozygote. Deviations from the expected ratio with respect to aleurone colors are common, but they are usually accompanied by gradations in the intensity of the color, while in this case the two classes were very sharply marked. Another cross between plants both from seeds with colored aleurone produced an ear with all the seeds red.

In a cross between a plant from a white seed of the Chinese (female) and a variety with black aleurone from Salvador the seeds all showed a mottling in the aleurone layer. None were pure black, though some were nearly pure white.

A cross between a starch variety grown by the Hopi Indians of Arizona with blue-black aleurone (female) and a white Chinese variety showed no trace of the white parent. This case is of particular interest, as the aleurone color in this Hopi variety is definitely recessive to colorless aleurone in the same variety.

Where plants from white seeds were pollinated among themselves, the result was in nearly every case a pure white ear. In six hand-pollinated ears among plants from seeds without aleurone color, four produced seeds entirely without aleurone color. The other two ears, while mostly white, produced in the one case 4 and in the other 6 seeds that showed aleurone color. Among the crosses with other varieties, 7 were between Chinese plants from white seed and other varieties without aleurone color; in every case the ears produced were entirely without aleurone color.

ENDOSPERM COLOR.

No crosses were made between Chinese plants from seeds with yellow and white endosperm, but from the appearance of the close-pollinated ears and those that were wind-pollinated it appears that the yellow is dominant, though varying in intensity, as with other varieties. All crosses between plants from seeds with white endosperm gave practically all white seeds, the exception being one poorly filled ear with 29 seeds, 4 of which had yellow endosperms. Since the same ear also showed seeds with horny endosperm, it seems not improbable that the precautions against foreign pollen were imperfect. Two crosses between plants from seed with yellow endosperms gave all yellow seeds.

ENDOSPERM TEXTURE.

The unique nature of the endosperm texture of this Chinese corn affords an interesting opportunity to study the behavior of definitely

contrasted characters. So far as observed every grain of the original seed of the Chinese corn possessed the characteristic waxy endosperm, while nothing of this nature has been observed in any American variety. Since the waxy endosperm is completely recessive to the horny and starchy endosperm of our common varieties, its appearance in all the kernels of the original seed would indicate that the seed was grown in a region in China where there was no admixture with varieties having a horny endosperm.

Eight crosses were made between plants from seeds with waxy endosperms, and in practically every case the seeds were all waxy. Six ears produced from crosses between varieties with horny and waxy endosperms produced only horny kernels; two between starchy and waxy varieties had starchy kernels only.

SIZE OF SEED.

It was apparent from open-pollinated ears of Chinese corn that the size of the seed was influenced by the nature of the pollen. Seeds which showed by their color and texture the effect of foreign pollen were in nearly every case distinctly larger than those showing pure Chinese characteristics. Twenty-one yellow, transparent seeds from the central portion of an open-pollinated ear of white Chinese had an average weight of 0.178 gram, while the white opaque seeds from the same portion of the ear averaged 0.153 gram to the seed. There was some variation in the size of the white seed, but 21 of the largest of these averaged only 0.161 gram.

Further experiments are needed to determine whether this increase in size is due to the inheritance of the size of a large-seeded male parent or whether the increase is another instance of the increased size of a hybrid over the average of the parent.

The following table summarizes the results of twenty hand-pollinations with respect to the characters that appeared in the same season that the crosses were made:

TABLE III.—*Xenia characters appearing in twenty crosses of Chinese corn.*

Types of parent plants.	No. of seeds.	Aleurone color.			Endosperm color.			Endosperm texture.		
		Parents.		F_0 generation.	Parents.		F_0 generation.	Parents.		F_0 generation.
		♀	♂		♀	♂		♀	♂	
China white × China white	470	Absent	Absent	100 per cent absent.	White	White	100 per cent white.	Waxy	Waxy	100 per cent waxy.
Do	480	do	do	98.6 per cent absent.	do	do	99.2 per cent white.	do	do	99.4 per cent waxy.
Do	560	do	do	100 per cent absent.	do	do	100 per cent white.	do	do	100 per cent waxy.
Do	300	do	do	do	do	do	do	do	do	Do.
Do	29	do	do	do	do	do	82.8 per cent white.	do	do	96.6 per cent waxy.
Do	280	do	do	do	do	do	99.6 per cent white.	do	do	100 per cent waxy.
White dent × China white	544	do	do	do	do	do	100 per cent white.	Horny	do	100 per cent horny.
Hopi white × China white	288	do	do	do				Starchy	do	100 per cent starchy.
White dent × China white	392	do	do	do	White	White	99.7 per cent white.	Horny	do	100 per cent horny.
Mexican dent × China white	504	do	do	do	do	do	100 per cent white.	do	do	Do.
Laguna × China white	350	do	do	do	do	do	do	Horny and starchy.	do	100 per cent horny and starchy.
Mexican shoe-peg × China white	200	do	do	do	do	do	do	do	do	Do.
Hopi black × China white	420	Present	do	100 per cent present.	do	do	do	Starchy	do	100 per cent starchy.
China white × Guatemalan black	180	Absent	Present	100 per cent mottled.	do	do	100 per cent ? white.	Waxy	Starchy	100 per cent ? starchy.
Mexican shoe-peg × China mixed	125			100 per cent absent.				Horny	Waxy	100 per cent horny.
China mixed × Mexican starch	431	Present ?	Absent	88.3 per cent present.						
China yellow × China yellow	400	Absent	do	100 per cent absent.	Yellow	Yellow	100 per cent yellow[a].	Waxy	Waxy	100 per cent waxy.
Do	560	do	do	do	do	do	do	do	do	99.8 per cent waxy.
China mixed × China mixed	320	Present ?	Present ?	100 per cent present.						
China red × China red	398	do	do	78.4 per cent present.						

[a] Many very pale.

HISTORICAL ACCOUNTS OF MAIZE IN CHINA.[a]

The discovery in China of a variety of maize with characters not known in American varieties of the species is not without interest from the historical point of view. Whether maize was known in the Eastern Hemisphere before the discovery of America was a warmly disputed question some decades ago, but since De Candolle's studies and his definitely negative conclusions were published, most writers have accepted his view.[b]

The finding of this unique variety of maize in China suggested a reexamination of the data on which De Candolle's conclusions were based. It now appears that important considerations have been overlooked and that the question is far from being settled. The issues have been confused by the failure to distinguish between two radically different points of view, the origin of the species in Asia and the possibility of its introduction into that continent in pre-Columbian times. Regarding the first question there can be but one opinion. Maize is of American origin. To many writers the mass of evidence that showed the widespread use and importance of corn in America at the time of the discovery seemed to preclude the idea that it could have existed at the same time in Asia. The other cultivated plants that are now known to have been extended on both sides of the Pacific show that the presence of maize in China would in no way conflict with the generally accepted fact that the maize plant is a native of America. The possibility that maize might have been introduced into China before the discovery of America by Europeans is to be considered quite alone on the basis of historical evidence.

The most significant evidence to the effect that maize was known in China before the discovery of America is not, as De Candolle states, the mention of maize in the mediæval "Charter of Incisa," now held to be a forged document, but the descriptions of maize that occur in Chinese literature. Very little information exists in Europe or America regarding the scientific writings of the Chinese, but enough is at present available to show that De Candolle's conclusions may need to be modified.

The first serious attempt to canvass this class of information is found in an article by Hance and Mayers.[c] At the request of Mr.

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[a] The writer is indebted to Mr. Walter T. Swingle for assistance with the literature concerning maize in China.

[b] See De Candolle, A. C., Geographie botanique raisonnée, 1855, vol. 2, p. 942, and Origin of Cultivated Plants (International Scientific Series), 1886, p. 387.

[c] Hance, H. F., and Mayers, W. F. Introduction of Maize into China, Pharmaceutical Journal, ser. 3, vol. 1, December 31, 1870, pp. 522–525. Dr. H. F. Hance, one of the foremost authorities on Chinese botany, went to China from England in 1844 and remained in that country until his death in 1886. Mr. W. F. Mayers, a recognized authority on the Chinese language, lived in China from 1856 to 1878. See Bretschneider, E., History of European Botanical Discoveries in China, pp. 632–695.

Mayers a memorandum on the history of maize in China was prepared by Mei K'i-chao, the intendant of the grain revenue for the province of Kwangtung. This memorandum includes a list of the common names of maize and their derivations. All references to the introduction of the plant are vague, except for the repeated and definite statement that it came to China from the west, more particularly from "Si-fan," a name formerly applied to a region to the west of China, including parts of Tibet and possibly Turkestan. Mei K'i-chao adds that there is a tradition in the provinces of Yunnan and Kweichow that maize was introduced there by Ma Fu-po from Cochin China. Mayers adds in a footnote that Ma Fu-po was known to have headed an expedition against the Si-fan tribes to the west in A. D. 36, and that he may have brought maize from there rather than from the south. In conclusion Mei K'i-chao says:

It is further noted that this grain was heretofore presented as tribute, but again no date is assigned. It is evident that its introduction must have taken place at a very early period; as, at the time when these works were compiled [1552 to 1632], no information could be procured.

In the article just mentioned Mr. Mayers gives translations of references to maize in early Chinese works. The most important of these is taken from the Pen ts'ao kang mu, a Chinese herbal or materia medica. The author, Li Shi-chen, was born in the early part of the sixteenth century and began this work in 1552. It was completed in 1578, having been rewritten three times by the author, and after his death was laid before the Emperor by the author's son and published the same year, about 1596.[a]

The figures of maize reproduced in Mr. Mayers's article are well known and have frequently been copied, but the translation seems to have passed unnoticed. De Candolle refers to the article, but admits not having seen it.

Mr. Mayers's translation of the paragraph of the Pen ts'ao kang mu that refers to corn is given below with very slight corrections.[b]

The seed of the *Yü-shŭ-shú* came from the lands on the West, and it is cultivated by but few. Its stalk and leaf both resemble the *Shŭ-shú* [sorghum[c]], but are more fleshy and shorter. They also resemble the [*i-i*] *Coix lachryma;* the stalk grows to a height of 3 or 4 feet; it flowers in the sixth or seventh month, producing an ear like that of the *Pi-mĕ*. From the heart of the stalk there issues a sheath in shape like the *Tsung* fish, from which a white waving beard grows out. After a time the sheath opens and the

[a] Bretschneider, E. Botanicon Sinicum. Journal of the North China Branch of the Royal Asiatic Society, n. s., vol. 16, p. 55. Shanghai, 1892.

[b] Book 23, p. 23 r°, edition of 1646, a copy of which is in the Library of Congress.

[c] Wu Ki-sün. Chi wu ming shi t'u k'ao (original part), book 1, p. 44, gives under this name an excellent picture of a compact-headed sorghum similar to the durras of northern Africa and western Asia.

grain comes forth. The grains are clustered together, each one as large as a *Tsung* seed [a palm, probably *Trachycarpus excelsa*], and yellow and white in color; they may be eaten baked or roasted. When roasted, they burst into a white flour-like mass, similar in appearance to that produced when rice of the glutinous kind is roasted.

The two figures given by Mayers from two different editions of the Pen ts'ao kang mu are crude and might be taken to represent any large-leaved, erect grass with a large terminal inflorescence. The text, on the contrary, leaves no room for doubt that the plant referred to is in reality maize. The height of 3 or 4 feet of course refers to Chinese feet of about 14 English inches. The "white waving beard" accurately describes the silks and would not apply to any other grass; this feature is shown in all the illustrations, even though the artist places the ear at the top of the plant. The opening of the sheath or husks can be understood, since the tip of the ear is commonly exposed in small varieties of maize.

Another contemporaneous reference to maize in China is given by Mendoza, an Augustine monk, who compiled the reports of the early Portuguese and Spanish missionaries in China, in a book published in 1585.[a] The first part, which contains the references to maize, was based on the accounts of Martin de Herrada and Geronimo Marin, who visited China in 1575. Herrada was a scholar familiar with the Chinese language, while Marin is described as "a native of Mexico, a man equally distinguished for his piety and learning."[b] To a native of Mexico the positive identification of maize would be certain, especially as the reference is made in the following specific manner:

On their high grounds, that are not good to be sowne, there is great store of pine trees, which yeelde fruite very sauorie: chestnuts greater, and of better tast, then commonly you shall finde in Spaine: and yet betwixt these trees they do sow maiz, which is the ordinarie foode of the Indians of Mexico and Peru.

The possibility of maize being a recent introduction would seem to be precluded by a second reference where this grain is referred to as one of the commodities paid as tribute to the King of China at a time that was considered ancient in 1575.

The rent which remaineth vunto the king ordinarily is this that followeth, and is taken with great regard out of the booke of his exchecker. Yet the Chinos do say that it is much lesse then that they do pay at this time; for that this is of old antiquitie, when as the tributes were lesse: . . .

The reference to maize as a tribute is as follows:

Of wheat called Mayz, twentie millions two hundred and fiftie thousand hanegs [about 30 million bushels].

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[a] Mendoza, Juan Gonzales de. The History of the Great and Mighty Kingdom of China. (Parke translation, 1588.) Hakluyt Society reprint 1853, pp. 15 and 84.

[b] Mendoza, loc. cit., p. lxix.

Another reference to the use of maize as tribute appears in the following extract from Mr. Mayers's article:

Apart from the Pun Ts'ao, notices upon the present subject have also been sought in the "*Kê Chih King-yüan*," or "Mirror of Classified Research," a vast cyclopædia of information in all departments of physical study practiced by the Chinese, with references under each heading to antecedent works. This collection, in twenty-four volumes, was published in 1735 by Chên Yüan-lung. It contains no reference to maize under the name of *Yü Shŭ-shú;* but describes the plant as *Yü-mê* (imperial wheat), in the following terms:

" *Yü-mê*, or imperial wheat, originated in the Si-fan territory (the lands beyond the western frontier of China proper), and its ancient name was *Fan-mê*, or 'wheat of the foreign lands of the West.' Having been offered among tribute, it has received the name of imperial wheat. In its stem and leaf it is the congener of the *Ts'i*, or panicled millet, and, in its flower, of rice. The sheath inclosing the ear is like a closed fist, but longer. The beard resembles red threads. The seed is like the grain of the *Tz* plant, but large, lustrous, and white. The flower blooms at the top of the plant, and the seed (ear?) grows out from the joints." (Loc. cit., p. 525.)[a]

If maize existed in China in very early times it may be expected that conclusive proof of the fact will be found in the pre-Columbian Chinese literature. Bibliographies of Chinese literature cite a number of cyclopedias and other large works, published before the discovery of America, that treat, at least in part, of agricultural subjects, but it does not appear that these have been scrutinized for references to maize. A study of this mediæval Chinese literature would doubtless go far toward settling this interesting question.

No very great significance can be attached to the absence of references to maize in the accounts of early European travelers in China. The only really detailed account of China before the discovery of America is that of Marco Polo, who traveled extensively in China during the thirteenth century. That even this account is far from complete, however, is shown by the omission of any reference to tea, a plant of much more importance than corn, and which is known to have been cultivated in China since 2000 B. C.

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[a] This paragraph is without doubt identical with one occurring in the Liu ch'ing ji cha of Tien I-heng, discovered by Berthold Laufer (The Introduction of Maize into Eastern Asia, in Congrés International des Américanistes, Quebec, 1907, vol. 1, p. 232), who makes the case even stronger by using the word "formerly" in his translation of the second sentence of the paragraph, which he gives as follows: "Since it was formerly brought as tribute to the court, it has received for this reason the name 'imperial wheat' (yü mai)." The Liu ch'ing ji cha is not cited in any European bibliography of Chinese literature, but since the passage in question was embodied in a work of Wang Shih-mou, who died in 1591, Professor Laufer infers that Tien I-heng wrote "say, about the middle of the sixteenth century." It thus becomes of importance to find the exact date of this publication, apparently the earliest known Chinese reference to maize. Professor Laufer's paper is full of valuable information on the history of maize in Asia, but unfortunately came into the writer's hands too late for full utilization in the present paper.

De Candolle's negative conclusion would seem to be fairly offset, at least, by the affirmative opinion stated by Doctor Hance as follows:

> In my judgment, the remote date assigned by Chinese records to its introduction and the circumstance that the introducer is unknown are irreconcilable with the supposition that it was brought to this country by the Portuguese, their first arrival here, under Fernand Perez d'Andrada, being, I believe, in 1517, and the earliest notice of maize in European literature dating later than 1530. To those, finally, who urge the conflicting and erroneous opinions of the earlier European writers as to the country whence maize found its way to the West as a ground for regarding Chinese statements with equal distrust, I would answer that it is not logical to apply the same canons of criticism to Western and Chinese literature, the latter being, at the period in question, in a very different and comparatively far more advanced state of development. (Loc. cit., p. 523.)

At the same time it must be admitted that the present facts can not be said to exclude the possibility that maize might have reached China after the discovery of America. Contacts between America and the Orient occurred very soon after the discovery of America, and in some cases at least were very direct. One expedition under Cabral left Portugal in March, 1500, and reached Brazil on May 1 of that year. It remained in Brazil twenty-two days, and then proceeded direct to India.[a] Opportunity was thus afforded for the carrying of maize from America directly to the East Indies instead of by way of Europe. It is very difficult, however, to believe that maize could have become established as a cultivated crop and spread into China in seventy-five years, even if a definite introduction had been undertaken promptly by the Portuguese. If varieties of corn similar to the Chinese are found in Brazil, the fact may have bearing on the historical question.

CONCLUSIONS.

The variety of Indian corn here described was introduced from Shanghai, China, and appears to be distinct from all hitherto known types. The plants possess the following unique characters:

(1) *Erect leaf blades.*—The leaf blades on the upper part of the plant stand erect instead of being borne in a more or less horizontal position, as in the ordinary varieties.

(2) *Monostichous arrangement of leaf blades.*—In addition to the erect position of the blades, those on the upper part of the plant are in many cases all on one side of the stem.

(3) *Silks developed while still inside the leaf sheath.*—Instead of the ear pushing out before the silks appear, the silks are produced directly at the base of the leaf blades, before the young ears emerge.

(4) *New type of endosperm.*—The texture of the endosperm is unique, and can not be referred to either the starchy or horny types

[a] Fiske, John. Discovery of America, vol. 2, p. 96.

common in our cultivated varieties. It resembles the horny endosperm in location and hardness, but differs in texture and optical properties.

The early development of silks and erect leaf blades combine to produce an adaptation which insures pollination and prevents the silks drying out. The pollen is blown against the erect leaf blades and accumulates in their bases. The silks are pushed into these accumulations of pollen and become pollinated before they are exposed to the air.

Xenia characters in hybrids appear for the most part to follow Mendel's laws. Colored aleurone is dominant to transparent aleurone; yellow endosperm is dominant to white endosperm, and horny endosperm is dominant to waxy endosperm.

The discovery in China of a distinct type of maize has bearing upon the historical question whether maize was known in the Orient before the discovery of America. Though maize undoubtedly originated in America, the nature of the historical evidence regarding the extensive cultivation of maize in China in the latter part of the sixteenth century seems to preclude the idea of very recent introduction, leaving open the possibility that this specialized type of corn has developed in China. The generally accepted view to the contrary is further thrown in doubt by references to its widespread use and introduction from the west that occur in Chinese literature published during the sixteenth century.

NOTE.—After the foregoing paper was in type a letter dated August 24, 1909, was received from Rev. J. M. W. Farnham, Mokansan, China. This letter confirms in a very gratifying way the ideas advanced regarding the adaptive significance of the peculiar characteristics of the variety of maize described in this bulletin.

With respect to the climatic conditions that prevail in the region where this variety of corn is grown, Mr. Farnham states, "There is usually a long dry spell at the time of flowering," and as an example of the effect of this dry weather on ordinary varieties he writes, "I have a good illustration of pollination failing in a dry time in a case of a small patch of 'Late Mammoth' from which we are now eating. In gathering corn for the table to-day I found that probably half the ears, though large and well formed, had not a kernel of corn on them. Also many of the others had but a few kernels. There was protracted dry weather when this patch of corn was pollenizing."

Mr. Farnham also confirms the suggestion regarding the orientation of the plants with reference to a prevailing wind. "About 30 per cent of the plants have their leaves this way [on one side of the plant] and where there is this arrangement they face south. As I have said, the wind blows from the south pretty steadily all summer."

Mr. Farnham further states that there is a considerable area of this corn grown about Lieu-oo, twenty miles southwest of Shanghai, but it is not considered the principal crop. It is usually planted between the rows of cotton and is left to occupy the field after the cotton has been picked. A similar variety is grown at Taitsong, near Soochow, and on the island of Ch'ungming at the mouth of the Yangtze. The type is believed to be of local origin, and has been known personally to Mr. Farnham for thirty or forty years.

PLATES.

DESCRIPTION OF PLATES.

PLATE I. (*Frontispiece.*) Chinese maize: Front and back view of the same plant. It will be noted that the leaf blades on the upper part of the plant are all on one side of the stalk and that they are erect and exceed the tassel.

PLATE II. Fig. 1.—Chinese maize, showing silks protected by the base of the leaf blade. The photograph here reproduced was taken some time after pollination and the enlargement of the ear has forced the sheath away from the stalk. Fig. 2.—Upper part of a Chinese maize plant, showing the monostichous arrangement of the leaf blades. The base of the tassel appears in the upper part of the picture.

FIG. 1.—PART OF PLANT OF CHINESE MAIZE, SHOWING SILKS PROTECTED BY THE BASE OF THE LEAF BLADE.

(Natural size.)

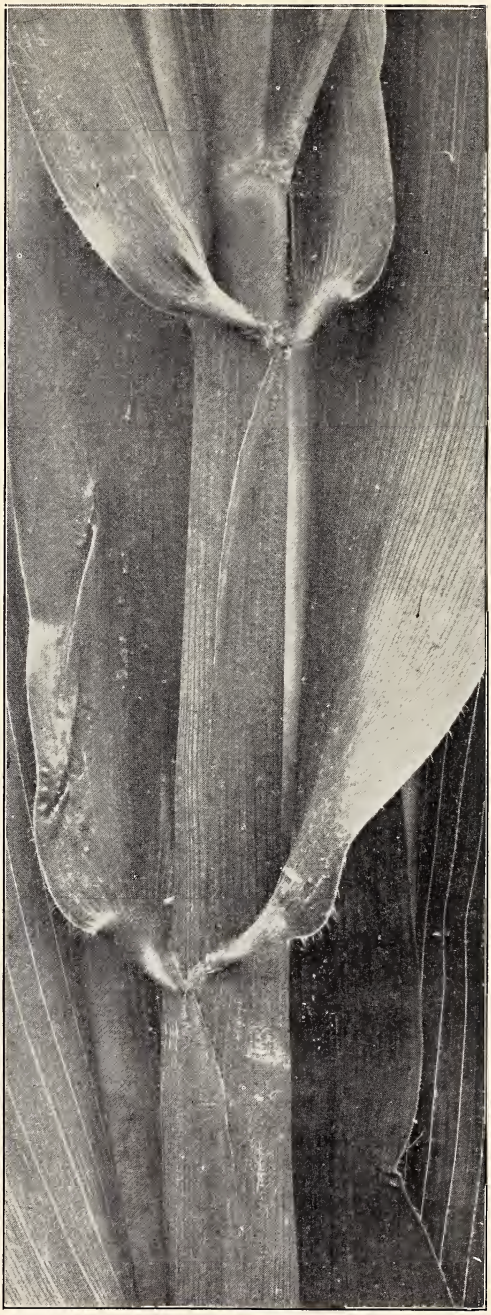

FIG. 2.—UPPER PART OF PLANT OF CHINESE MAIZE, SHOWING MONOSTICHOUS ARRANGEMENT OF THE LEAF BLADES.

(Natural size.)

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